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COSTING: GENERAL CONSIDERATIONS *

by

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To put costing in its perspective, I invite you to dwell upon the primary objective of the business enterprise.

Profit v/s Profitability

There is no doubt that commercial enterprises are profit motivated. Whatever the stigma attached to this, it still makes sense - indeed a lot of sense - that profit remains the sole motivation of business promoters. Profit should, however, not be confused with the profitability of the enterprise.

In trying to define profit and profitability, we are already in the domain of costing. Profit as you all know is the difference between the selling price and the cost of making a product. More precisely, it is the identifiable gain resulting in the form of excess value on selling price as compared to the cost of the product or service. Profit relates to one specific product/line of product or service.

Profitability, however, relates to the overall operation of the enterprise. It is influenced by management decisions taken to enhance the earning capacity of the firm which may be operating at a profit or less in the short term. Obviously then, profitability concerns itself with the long term survival of the enterprise. The rationality of management decision to earn a profit in the short term certainly goes a long way to enhance and ensure a fair level of profitability of the enterprise. It also goes without saying that profitability can exist without profit - for example, in the case of potential gain (long term) as against a current loss. This may occur in the case of a new venture or a product line, or in the case of a "product leader".

It has been seen that variable or marginal costs vary directly with production, whereas fixed costs remain fixed regardless of the volume produced. This cost behaviour, when related to sales income shows the cost/volume/profit relationship which is the net effect that change in cost, price and volume has on profits.

The relationship between costs and revenues, and therefore profits, at different levels may be expressed graphically, in the form of a "break even chart" or in a statement form, as shown hereunder:

Cost Statement of a Simple Product

		Product A
Sales value		x
less marginal cost:		
prime cost	x	
variable overhead	x	x
contribution		x
less fixed costs		x
profit		x

The above statement offers the advantage of computing and presenting the cost of a group of products and their individual contribution towards the enterprise, fixed costs, and the profitability of each product. It may be that one product has no contribution and has a loss, which in theory should be omitted. In practice, however, this product (termed as a "loss leader") is retained as it is a booster to other products in the line.

Any increases in the profit margin will obviously ensure a better profitability right from the start. Management therefore decides whether or not a policy of immediate profit is viable in the current business environment (i.e. competition). Increasing profit means maintaining or reducing costs and increasing prices. All of these variables may not be as easy to change in the short term period. In many instances, selling price is unalterable - in fact has to be kept to the lowest possible level to confront competitors. The choice therefore is limited to cost reductions. Admittedly there is no magic formula to cost reductions. Constant efforts are, however, made - for example, a value analysis engineering exercise does sometimes yield the desired results - to decrease production costs.

Product pricing, generally is dictated by the level of competition in that particular field of activity. Product pricing policies are again an important concern for management. A pricing policy will be determined by the marketing strategy of the organization, which may be:

- market penetration
- market development.

The pricing policy may also at the same time focus on a satisfactory rate of return on investments. Whatever the pricing policy is, it is important to note that the price of a product should reflect a fair and reasonable value that the buyer is prepared to pay for the product. Admittedly, product pricing and product costing often appear to be a difficult and easy process at the same time.

It is difficult because of the lack of precise market information, unfair competition, difficulties of costs identification, their classification and allocation, laying down in precise terms the criteria for a pricing policy compatible with the firm's objective and the implementation of a marketing strategy. It may be easy, because fortunately enough, there are already certain fundamental costing and pricing systems developed to assist in the scientific computation of costs and their eventual use in the pricing of the product.

The crux of the subject, therefore is to arrive at a right balance between a product cost and the product price which will yield the highest profit margin and eventually will ensure the firm's profitability.

Costing

We will now move to costing proper.

Costing may be defined as "The techniques and processes of ascertaining costs". This can be expanded: "The classification, recording and appropriate allocation of ex-

penditure for the determination of the costs of products or services, the relation of these costs to sales values and the ascertainment of profitability".

These costs may be ascertained:

(a) historically, that is, after they have been incurred, or

(b) by predetermined standards, combined with subsequent analysis of variances between those standards, and the actual cost incurred and

(c) by the use of marginal (costing) methods of presentation for either (a) or (b) above, involving the differentiation between "fixed" and "variable" costs.

Why costing/cost accounts?

Costing enables a business not only to find out what various jobs or processes have cost but also what they should have cost: it indicates where losses and waste are occuring before the work is finished and therefore immediate action may be taken,if possible, to avoid such loss or waste.

Business policy may require the consideration of alternative methods and procedures and this is facilitated by cost information correctly presented. For example, by the aid of cost reports management can decide whether the manufacture of certain products increases overhead expenditures disproportionately, whether to treat by-products even if at a loss, to make possible a more important trade in another product, whether the plant and machinery could be used more advantageously by concentrating on particular products to the exclusion of less profitable ones, or whether prices could or should be adjusted.

To bring out the importance and significance of the above, let us consider a simple illustration.

The following information is supplied by the financial accounts:

Materials consumed	20,000
Wages paid	15,000
Other expenses	18,000
Total cost	53,000
Sales	60,000
Gross Profit	7,000

The cost accountant, however, will proceed with a breakdown of the above figures, assuming that three different products, A, B and C were manufactured.

	Product A	Product B	Product C	Total
Materials	7,000	8,000	5,000	20,000
Wages	8,000	5,000	2,000	15,000
Other expenses	10,000	6,000	2,000	18,000
Total Cost	25,000	19,000	9,000	53,000
Sales	30,000	18,000	12,000	60,000
Gross profit	5,000	- 1,000	3,000	7,000

It is now clear that the total expenditure of Rs 53,000 is classified into the elements (materials, wages and other expenses) and then the cost against each element is allocated or apportioned to the three products to give the cost of each. If the number of units manufactured is given, then the cost per unit for each product can be determinted that is, suppose 100 units of product A are produced:

	Cost of Product A Total cost	100 Units Cost/unit
Materials	7,000	70.00
Wages	8,000	80.00
Other expenses	10,000	100.00
	25,000	250.00

Referring to the above simplified figures, it may be clear that cost accounting therefore gives a better view of the operations in the production department with a view to securing management cost control. Although the gross profit was Rs. 7,000.- the cost records show that product B incurred a loss of Rs.1,000; a situation which the financial records failed to reveal.

Elements of Cost

Generally speaking all expenditures may be divided into groups corresponding to the activities of a manufacturing concern, that is:

- Production Department
- Service Department (maintenance)
- Works expenses (factory building repairs)
- Administration expenses (office salaries, postage, telephones, etc.)
- Selling expenses (commission, discount to customers, etc.)
- Distribution expenses (cost of running a delivery van, etc.)

Again, we have seen earlier that the total cost of a product can be separated under the three broad headings:

(a) material cost
(b) labour cost
(c) overhead cost.

These three groups of expenditure constitute the elements of cost.

Cost Classification

Functional costs

Referring to the above functions of a manufacturing concern, we have basically the following types of cost:

- manufacturing/production costs
- administration costs
- selling and distribution costs
- research and development costs
- pre-production costs

The above types of costs are self-explanatory. It should be noted that these costs would be significant depending on the size and nature of enterprise.

Attributable costs - direct/indirect:

In certain cases, costs are easily identifiable and therefore, attributable to a particular product or service. While in other cases, these costs are not directly associated with the products but their existence has an equal importance in the organization.

Thus, costs are direct or indirect to the product.

(1) Direct materials cost is the cost of materials which can be identified with and allocated to cost centres or cost units. Direct material is that material which becomes a part of the product. However, there are some material which becomes part of the product, but are used in comparatively small quantities and have very negligible costs. Such materials are conveniently grouped under indirect materials as part of overhead. Materials, including component parts, specially purchased or requisitioned for a particular job, order or process are direct materials. Likewise, materials passing from one operation or process to another; and primary packing materials such as cartons, cardboard, boxes, etc. are direct materials.

(2) Direct wages (labour cost) are the wages which can be identified with and allocated to cost centres or cost units. They constitute the expenditure made to alter the condition, conformation or composition

of the finished product. Wages of foremen, inspectors, chargehands, whilst not directly expended as defined above, are for costing purposes, considered as direct wages.

(3) Direct expenses (other than direct material or direct wages) that are attributable to product take the form of cost of special designs, drawings or layout, hire of special tools or equipments, etc. for the job.

(4) Indirect cost or overhead expenses are all other expenses that cannot be easily traced to a particular product.

Variable/fixed Costs

We also classify costs as variable or fixed in relation to time and output. Fixed costs do not change in output level over a short period of time (i.e. office salaries, rent, travelling etc.). Variable costs, however, change with variations in output. It is also to be noted that total cost varies with the output level. The reverse is true in case of variable costs. The distinction between fixed and variable costs is very important in the context of marginal costing - a technique commonly used by management to determine the product mix and for assessing the effect of change in volume on profitability.

Total cost

The above classifications of costs lead to the following:

(a) Direct material
(b) Direct labour
(c) Direct expenses
(d) Overhead
  (i) Production
    1. departmental
    2. general
    3. services
  (ii) Administration
  (iii) selling and distribution

Prime cost = (a) + (b) + (c)

Production or factory cost = Prime cost + (d)(i)

Total cost of sales = Production or factory cost + (d)(ii) + (d)(iii)

Statements of Total Cost

The total cost is made up of costs incurred in producing (converting the raw material into finished products by the help of labour, machine, etc.) and selling (distributing) the product. The total cost statement may be presented as follows:

Statement of total cost

1.	Direct material cost	.....
2.	Direct wages	.....
3.	Direct expenses	.....
	Prime cost	.....
4.	Production or factory overhead	.....
	Production or factory cost	.....
5.	Administration overhead	.....
6.	Selling and distribution overhead	.....
	TOTAL COST	.....

The above presentation of cost information yields the advantage of analysing the various cost elements as a percentage of the total cost. It therefore assists management in exercising cost control methods.

Cost centre and cost unit

Prior to the installation of a costing system, it is important to know that costs are identifiable (ascertained) at a cost centre or as cost per unit. The cost unit is a unit of product, service or time. The selected unit is measurable and is one with which expenditure is most readily associated and is generally a unit clearly appropriate to the business - i.e. cost of one table, filing cabinet, cupboard, etc.

A cost centre is a location, person or item of equipment (or group of these) for which costs may be ascertained and used for the purpose of cost control. Examples of cost centres:

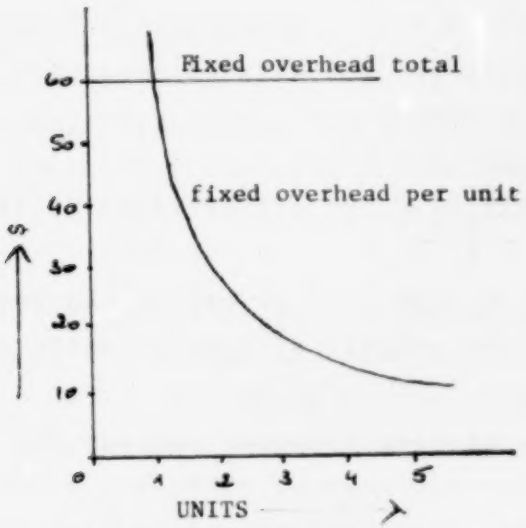
Production cost centres	- regular production of goods or services
Operation cost centres	- machine/group of machines or persons carrying out similar operations
Process cost centres	- machines/persons engaged or a specific process or a continuous sequence of operations

Cost centres and cost units are either allocated or apportioned with the indirect costs. Cost allocation refers to the allotment of the whole items of cost to cost centres or cost units. Cost apportionment is the allotment of proportions of items of cost to cost centres or units. Whereas a greater degree of precision may be observed in allocation, apportionment, however, requires an effort to obtain a reasonable degree of precision.

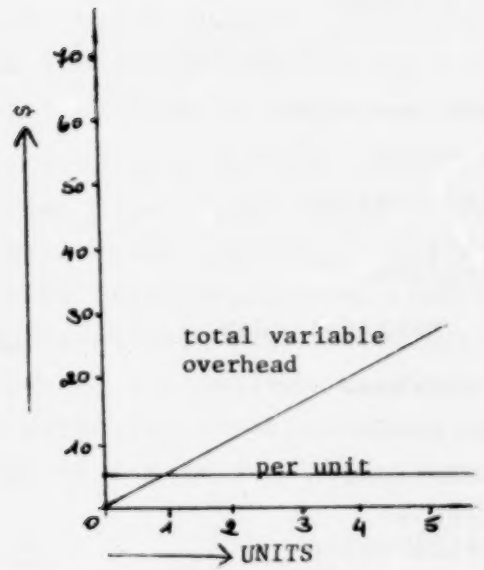
Absorption costing v/s marginal costing

The absorption costing method provides that the aggregate of the costs incurred during the particular period and irrespective of the level of output, are chargeable to the production - that is, all costs during the period are absorbed of the production. When costs (expenditure) are segregated into their particular functions and variability, a different costing method comes into the picture. Fixed costs vary in function with level of output and time. Whereas the total fixed costs are constant over a period fixed cost per unit of output varies. The reverse is true for variable costs - that is unit variable cost is the same, but the total variable costs will vary according to the level of output. See the figures below.

Production	Variable OH per unit	Total variable OH	Total fixed OH	Fixed OH per unit
Units	$	$	$	$
1	5	5	60	60
2	5	10	60	30
3	5	15	60	20
4	5	20	60	15
5	5	25	60	12



FIXED OVERHEAD CHART



VARIABLE OVERHEAD CHART

Marginal costing method thus provides for the distinction in the nature (variability) of cost elements. Fixed costs are chargeable to the profit and loss account during the period. Only variable costs are charged to the production. This costing method is used to show the effect on profit of changes in volume or type of output.

The break even point is that volume of sales or production where there is no profit or no loss. From the above statement, the B.E.P. can be reached as follows:

$$S - M = F + P$$

where S = sales, M = marginal/variable cost, F= fixed cost and P = project

At B.E.P., P = 0

Multiplying by S and rearranging, we have

$$S_{BEP} = \frac{F + S}{S - M}$$

The B. E. P. can also be calculated using the P/V ratio (profit volume ratio), or the C/S ratio (contribution to sales ratio).

Under the marginal costing method, the statement of total cost is:

1.	Direct material	-
2.	Direct wages	-
3.	Direct expenses	-
	Prime cost	=
4.	Variable overhead	
	Production -	
	Administration -	
	Selling + distribution -	
	Marginal cost	=
5.	Fixed overhead	
	Production -	
	Administration -	
	Selling + distribution -	
	TOTAL COST	=

The usefulness of the various costing methods is found in the purpose and objective of management. Cost accounting - costs classification, recording, presentation of cost statements, their analyses - is an important management tool, in so far as proper control of expenditure is possible with a view to minimizing product costs and maximizing profitability. The rule-of-thumb method of costing generally common in certain industries must give way to a more systematic and planned costing procedure.

Costing and Financial Management

Costing, as we have seen, can be advantageously used to better management practices. It plays, thus, a significant role in the profit planning of the enterprise and offers an effective means to plan and control the financial operations of the business.

In applying a costing system, management predetermines or estimates the financial commitments that the enterprise take in hand. For example, the budgeted materials cost, labour costs and the overhead expenses are predetermined against which the sales revenue are compared to strike a profit or loss during the ensuing period of operations. Thus, the liquidity problem is highlighted implying a sound cash management system. The lack of liquidity can be a serious handicap to the successful operation of the enterprise. Excess of liquidity, too, is not a sound practice to follow. A right balance is therefore imperative.

The first step towards this equilibrium is then the peparation of a cash flow. Cash inflows consist of, essentially sales revenues, new capital, loans and short-term borrowings, debts collections, income from other sources (or non-operating revenues), etc. Cash outflows, on the other hand, consist of all outlays made towards material purchases, wages payments, administration costs, etc. Accounting entries of a purely notional nature, such as

depreciation or notional rent, do not constitute cash outflows. The balance (excess) on cash inflows or outflows result in a positive or negative cash flow balance.

It therefore goes without saying that a proper costing system is more of an asset than a liability to management inasmuch as it assists management in alleviating much of the fear of a chronic liquidity problem that can become the real danger and jeopardize the very survival of the enterprise. Costing should be taken seriously if the entrepreneur/manager wishes to have a better control over his financial management and thus avoid unpleasant surprises - refusal of payments by the banker of his obligations, or reluctance of shareholders/investors to inject more funds in the operations and so on and so forth.

I hope this short exposure has helped you to grasp some of the fundamentals of costing in any business situation. If it has, then I have no doubts you will become the more promising and effective manager that you want to be.

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WOOD PRESERVATION *

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INTRODUCTION

Wood preservation, in its widest sense, implies the protection of wood against any factor whatsoever that may damage and ultimately destroy it. No timber is immune to deterioration if exposed to atmospheric conditions. The serviceable life span of an organic matter like wood varies with the species concerned, the age of the wood when green, the natural properties or durability of the wood, the use to which the wood is put and so on. A study of wood preservation should, therefore, cover a very wide field of investigation but most work in recent years has been concentrated on the chemical treatment of wood and wooden products with the object of extending their life and improving their serviceability. Gamma rays too have been used to preserve wood, but this is beyond the scope of this paper.

Wood is not necessarily a rapidly perishable material. In fact, it has lasted for very long periods in Egyptian tombs, in old buildings and excavations of early civilizations. Under certain conditions, even the most durable timber like teak and western red Cedar may not last long if left in a warm, damp and ill-ventilated environment.

The chief causes of the deterioration of wood that is in use, as opposed to deterioration during seasoning, are:

(a) fungal infection;
(b) insects like termites, beetles, marine borers;
(c) mechanical failure; and
(d) fire.

It is in the protection of timber from damage by these agencies that wood preservation finds its main uses. Usually, preservatives are applied to non-durable timbers to make them become more resistant to the agents of deterioration, so that they can replace naturally durable timbers which are becoming more expensive and rarer on the market. It must be emphasized, however, that the mere application of a wood preservative does not necessarily ensure immunity to attack by insects, fungi and marine borers; much depends on the method of application and the type of preservatives used. If the absorption is good, the service life of the timber may be very long, depending on the quality of the preservative and the conditions in which the timber is used. On the other hand, if the preservative is merely brushed on, the period of immunity will be short.

Let us now consider, in turn, the preservation of wood against

(a) fire;

(b) wear or failure;

(c) insect and fungal attacks.

FIRE PROOFING

Wood, no doubt, is highly combustible but non-inflammable. It is true that under certain favourable conditions any wood, even the poorest firewood, may be burnt to ashes but it will not be readily ignited. Thin boards are more readily destroyed by fire than large cross-section timbers. The latter may continue to support a building, even after a prolonged period of fire, because the exposed surfaces become covered with a layer of charcoal that retards combustion. Experience has shown that a building constructed of heavy timbers has a greater fire resistance than many structures of steel. On the one hand, iron and steel expand and buckle at high temperatures, while on the other, bricks and stones chip and crack. Moreover, wood is not a good conductor of heat and may delay the spread of fire by slowing down the transmission of heat from one area to another.

Nevertheless, wood does burn at comparatively low temperatures particularly when it is air-dried. Wood heated to a temperature of about 250°C will decompose producing inflammable gases and charcoal. There are a number of substances that will increase the fire resistance of wood. These substances, generally known as fire retardants, are of two types:

(i) those injected by pressure impregnation; and

(ii) those applied to the surface by brushing and spraying.

Those injected by pressure usually make use of a fire-retardant chemical that under heat, will increase the yield of solid charcoal and water vapour at the expense of inflammable vapours. The latter are produced in insufficient quantities to feed the fire. The best known of these chemicals are monammonium phosphate, boric acid, borax and diammonium phosphate.

Fire retardant paints have a limited value and practical application. They are not as good but still they may help. The following formula for a fire retardant paint has been proposed by the British:

Sodium silicate	50 kgs
Kaolin	70 kgs
Water	50 litres

Such a paint should be applied by two brush coats or by spray to cover about 3 m^2 per litre.

Fire prevention and control methods include the usual precautions against fire, such as the provision in buildings of fire buckets and/or chemical fire extinguishers. In sawmills and cabinet makers' shops, the fire hazard can be greatly reduced by keeping the site as free as possible of sawdust and waste.

WEAR OR FAILURE

Wear or failure can occur in two ways:

(i) mechanical wear;

(ii) weathering.

The most common form of mechanical wear is abrasion caused either by the feet of pedestrians continually passing over a floor, or by the wheels of vehicles passing over bridges, wharves, warehouse floors, etc. A soft timber may be completely worn out. The only practical way to prevent abrasion is to use timber which is sufficiently hard and dense to resist it. Among the local timbers that are good for these conditions are Labourdonnaisia glauca (rare), Mimusops petiolaris (rare), Eucalyptus robusta (fairly common), Terminalia arjuna (fairly common), Acacia eburnea (fairly common). Burma Teak, Malaysian Kempas (Koompassia malaccensis) and the Australian jarrah (Eucalyptus marginata) are the most widely used timbers where hard wearing qualities are required.

The weathering of wood is caused by several factors, but primarily by repeated movements of the surface layers exposed to changing atmospheric conditions. This type of deterioration may be accentuated by fungal attack, the abrasive effect of rain and windblown particles of dust and sand, and also by chemical changes induced by light and a slow form of oxidation. Weathered timber loses its natural colour, and in general assumes a uniform light grey appearance; in timbers showing annual rings the softer summer wood is worn down and the dense spring wood appears as raised ridges. Treatment with suitable preservative or the application of paint or varnish will protect wood against weathering, provided such protective coatings are renewed regularly.

FUNGI AND INSECTS

Wood preservatives are essentially used to increase the resistance of timber against insect attack and fungal infection. Several substances have been used as wood preservatives, some have proved to be very good, whilst others are worthless but none can claim to be excellent in all circumstances. The following are considered:

(i) the properties of preservatives;
(ii) the types of preservatives; and
(iii) the methods of application.

(i) The properties of wood preservatives:

In using wood preservatives, it is important to bear in mind for what use and under what circumstances the wood will be used. A water soluble preservative may be good for indoor use but useless for outdoor work. On the other hand a preservative with a pungent smell may be good for outdoor work but totally undesirable for household use. The qualities demanded of a good wood preservative are that it should be:

(a) highly toxic to fungi and insects;
(b) permanently fixed in the wood;
(c) able to penetrate the wood easily;
(d) easy to apply and not dangerous to those handling it;
(e) not injurious to men and animals once in the wood;
(f) non-corrosive to the wood itself or to metals;
(g) cheap and readily obtainable;
(h) without tendency to increase the inflammability of the wood;
(i) odourless;
(j) colourless and not affecting paints, varnishes, glues, etc.

The first three properties are essential, but the last two are very important for the furniture and joinery industries. Not one preservative has all these properties.

(ii) Types of Wood preservatives:

There are three classes of wood preservatives:

(a) The tar oil group, comprising creosote and many patented or proprietary oil preservatives;

(b) water soluble salts, for example, zinc chloride, sodium fluoride, copper sulphate, mercuric chloride, arsenic salts, etc; and a number of proprietary mixtures; and

(c) solvant-types consisting of a toxic chemical dissolved in oil or spirit or other volatile liquids.

(a) Tar-oil derivatives:

Creosote is probably the best known preservative and is very widely used. It is a very complex substance with over 200 odd constituents, which may possess valuable toxic properties. It is used in exposed conditions in tropical climates where the humidity is high and the rainfall is heavy.

It was widely used formerly in Mauritius to treat sleepers when the railways were still a common mode of transport.

It cannot be used in the furniture and joinery industry because the timber can no longer be painted or varnished as the creosote creeps out. It becomes highly inflammable as well.

(b) Water soluble salts:

The common water soluble salts are zinc, chloride, copper sulphate, etc. Some of these salts are essentially fungicides whereas others are good insecticides. The copper salts are good fungicides and arsenic preparations are good insecticides.

CCA, which is used in Mauritius, is a mixture of copper/chrome/arsenic. If used properly, it protects wood against decay, borers and termites.

CCA can be used both for indoor works and for outdoor and exposed conditions as the preservative is "fixed" by chemical reaction within the cells of the wood and has a high resistance to leaching. It can be used at various concentrations depending on what use the timber will be put to.

CCA treated timber is clean and may be painted, nailed, glued and varnished. Once the preservative is in the wood, it is safe to human beings, animals and plants. It is not oily and it does not increase the fire hazard. Moreover, the wood does not smell and the substance is non-corrosive.

(c) Solvent types:

These preservatives consist of toxic substances soluble in a volatile solvent. They are more expensive than the water-soluble ones. Most

of them are reasonably permanent for both interior and exterior use.

Besides these three types of preservatives there are certain highly volatile substances like hydrogen cyanide which can be used as fumigants. They are highly toxic and can kill insects like pinhole borers that are present in certain pieces of furniture.

PREPARATION OF WOOD BEFORE TREATMENT

Timber must be in a suitable condition for treatment and this depends on species and the preservative to be used. Some treatments are applicable to green timber, but the majority requires more or less seasoned timber to secure good results. As a general rule, the moisture content should be reduced to 25 percent.

The necessity for seasoning is two-fold:

(a) moisture must be removed from the cell cavities of the wood to allow the preservative to penetrate; and

(b) it is preferable for seasoning defects to develop before treatment, since if such defects occur after treatment, unimpregnated areas of wood may be exposed.

During the seasoning period care must be taken to avoid serious seasoning and fungal defects. All bark must be removed as they are impermeable to liquids and they slow down drying. The wood must be worked, that is planed, mortised, etc. before treatment.

METHOD OF TREATMENT

There are five ways of applying wood preservatives:

(i) by brushing;

(ii) by dipping;

(iii) by open tank;

(iv) by pressure processes;

(v) by the Boucherie process; and

(vi) by dip diffusion.

The first three give very superficial treatment and are not very effective. The fifth one is used for green poles. The fourth one, that is the pressure treatment method is the one used in Mauritius. The sixth one can achieve good penetrations but can take a long time.

Brushing:

Brush coating is simple and inexpensive but is generally only effective for a very short time. If ever slight checks open as the brush treated timber seasons or if the coating is accidentally scrapen off in small regions, untreated wood is exposed and the interior may be attacked very rapidly; brush treated sapwood members are commonly seen reduced to a shell by powder post beetles within a few months. The most serious danger is that the coating will not be complete to start with, so much so, that the wood is exposed to rats and insect damage including termites.

The best preservatives for brushing are the high quality creosotes or proprietary brands of this type, but extravagant claims for the efficency of any preservative that is only brush coated must be regarded with suspicion.

Dipping:

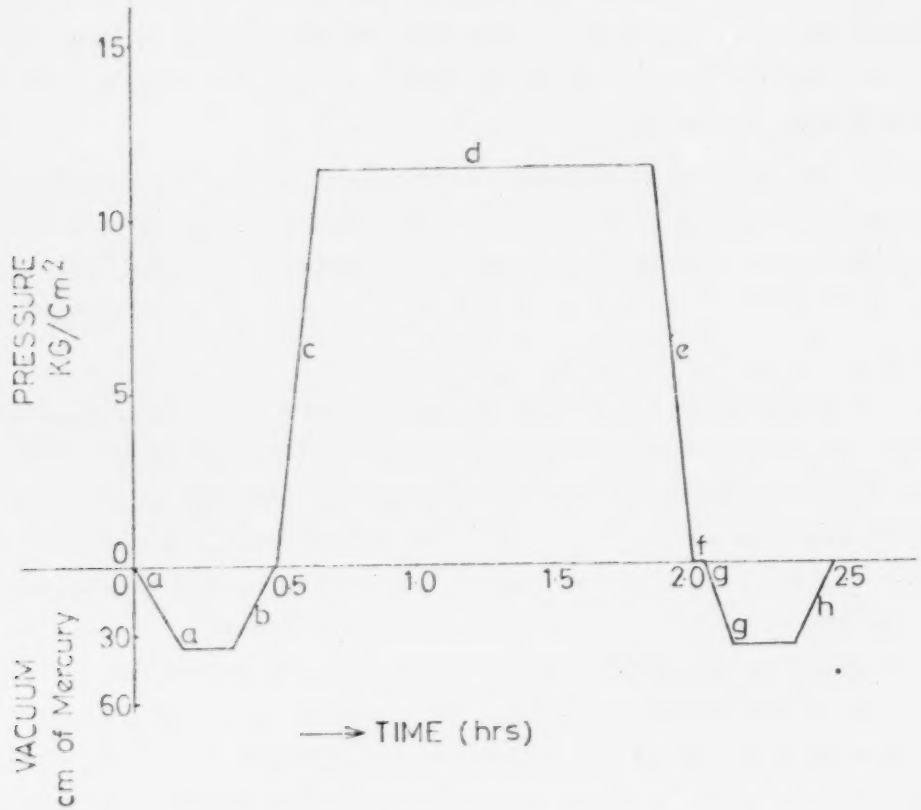
Dipping can be carried out hot or cold. The hot method can only be carried out for those preservatives that can be heated. The dipping tank is filled with hot liquid and the clear timber is immersed in it. Dipping foı a short time say up to a quarter of an hour or so, is not more effective than brush coating except in the case of the highly volatile preservatives. This method can only be justified with thoroughly seasoned timber. Dipping may afford quite an appreciable amount of protection to the ends of timber in contact with other timbers, bricks, or concrete as the preservative is more readily absorbed by the section of the timber than on the surfaces. This applies especially to those timbers that can be readily impregnated.

There is no advantage in dipping timbers in the creosote-oil type of preservative for more than three to four hours, but with water-soluble salts absorption by diffusion may go for indefinite periods of time. Hence the process of steeping, which consists in submerging wood in a water solution for a period of several days or even weeks. With this method of treatment, using water soluble salts, the results with green timber are sometimes better than with seasoned timber.

Pressure process:

The main item is a pressure cylinder capable of standing pressure up to 14 kgs per cm^2 or more, and fitted with one door that can be hermetically sealed.

In addition, air and vacuum pumps, hydraulic or centrifugal pumps, mixing tanks and storage tanks must be provided. This process can be varied to suit the type of timber being treated and the amount of absorption required. The method used here is the full cell process,that is a vacuym is applied to the timber before the preservative is admitted to the cylinder. The following graph explains the steps during the treatment.



LEGEND: (a) preliminary vacuum period; (b) fill cylinder with preservatives; (c) build up pressure; (d) maintain pressure level; (e) release pressure; (f) empty cylinder of preservative; (g) final vacuum period - keep emptying cylinder of preservative; (h) release vacuum.

Boucherie process:

The Boucherie process, with modifications, is used exclusively for the impregnation of green poles with water-soluble salts. The poles must be treated within a day or two of being cut and the bark must not be removed. The

preservative is fed through a tube to a water tight cap fixed over one end of the pole, the tank containing the preservative being placed at about two to eight metres above the end of the pole. Under gravity, the solution passes along the wood vessels and permeates the timber; when it drips from the uncovered end of the pole, impregnation is complete.

Dip diffusion:

Some countries are showing great interest in dip diffusion treatments, particularly in remote areas. As soon as the green timber is sawn, it is dipped in a very strong solution of certain chemicals and then stacked without stickers for a long period to allow the salts to diffuse into the water in the wood cells. When sufficient diffusion is judged to have taken place, the timber may be seasoned on stickers in the usual way.

ABSORPTION REQUIRED

The amount of preservative that should be impregnated into a timber depends primarily on the purpose for which it is to be used. The retention normally practiced for CCA preservative is 6 kgs per m^3 for interior work and for furniture and joinery and for exterior off-ground contact 10 kgs per m^3 for exterior and ground fencing poles and very exposed timber. Timbers differ greatly in their amenibility to treatment by any particular impregnation process. Appendix I makes a comparison as poor, moderate and good in the absorption of CCA under pressure for different wood species.

CONCLUSION

As wood is becoming a relatively rare and expensive natural resource, it is best to increase its durability by treating it against decay and insect damage. In so doing, a new value is added to the wood and to the pieces of furniture that are all being manufactured with love and labour.

APPENDIX I

Comparison of the absorption of Tanalith C under pressure by different timber species

Common name	Latin name	Poor	Moderate	Good	Remarks
Araucaria (sapin)	Araucaria cunninghsmii			x	
Badamier	Terminalia catappa		x		
Bois de Natte	Labourdonnaisia glauca	x			Improves the figure
Camphor	Cinnamomum camphora			x	
Cassis	Acacia eburnea	x			
Cedar	Cryptomeria japonica		x		
Cypres	Juniperus bedfordiana			x	Very low concentration in order not to spoil the colour of the wood
Eucalyptus	Eucalyptus tereticornis	x			
Filao	Casuarina equisetifolia			x	
Mahogany	Swietenia mahagoni				Naturally durable
Pine	Pinus elliottii			x	
Tecoma	Tabebuia pallida			x	Same as Juniperus
Gurjun	Dipterocarpus glandiflorus			x	
Imbuia	Phoebe porosa				Naturally durable
Iroko	Chlorophora excelsa				Naturally durable
Kapur	Dryobalanops aromatica				Naturally durable
Kempas	Koompassia malaccensis		x		
Keruing	Dipterocarpus cornutus			x	
Meranti	Shorea spp.	x			
Muninga	Pterocarpus angolensus		x		
Sapelli	Entandrophragma cylindricum				Naturally durable
Teak	Tectona grandis				Naturally durable

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FOAMS USED IN UPHOLSTERY *

by

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INTRODUCTION

This paper discusses foams used in upholstery and to be a bit more specific, about foams used in upholstery in the furniture trade. These fall in two distinct categories: foams made from natural products - mainly rubber foams, of which perhaps DUNLOPILLO is the best known trade name, and those manufactured from artificial resins such as Polyester and Polyurethane and which have come to be collectively known as "plastic" foams.

After the second world war and up to the early seventies rubber foams, though expensive, reigned supreme for seating, backrests and bedding. The plastic foams were in infancy and rather expensive; and the qualities in many cases left much to be desired. Then came a very rapid development in the chemistry and technology of artificial foams - specially on the catalyst and the stabilizer side and the advent of the one-shot process on the equipment side - and in a very short lapse of time the so-called artificial foams have but completely superseded the use of natural rubber foams in the furniture trade. Polyester and polyurethane foams developed side by side but with the highly specialized equipment required for the former and coupled with its limited qualities it soon occupied a small and very particular niche in upholstery.

The vulgarization of methods of manufacture for polyurethane foams by the one-shot process made it at the same time, more accessible and more widespread all over the world. These foams - in their rigid, semi-rigid and flexible forms - are now made by various methods which range from the very simple, mixing by hand in a couple of buckets, to the fully automated, with fully automatic machines producing blocks up to five metres in width, one to one and a half metres in height and of unlimited length.

Thus, at present, polyurethanes form the bulk of the foams used in the furniture industry, and, the discussion will centre around this particular product. Such a review can hardly be contemplated without brief reference to the technical and commercial development which contributed to the establishment of this major industry, and one may perhaps start by recording that some of the basic chemistry associated with the subject was first observed as early as the 1880's, when laboratory attention was given to some fundamental reaction of the isocyanates. At this early stage, the observations made were of little more than academic interest, and it was not until the early 1930's that any

major research was directed towards the study of reactions which involved di-isocyanates and hydroxyl materials.

Such commercial objectives as existed at the time lay more in the field of synthetic fibres and elastomers, but no major break-through occured during the pre-war period. During World War II, shortages of certain natural materials led to more serious consideration being given to the commercial production of elastomers, mainly intended as rubber substitutes.

In the years immediately following the war, attention shifted towards investigation of flexible polyester foams, and commercial production started in the early 1950's. Their usefulness was, however, limited in scope at that time due to prevailing high raw material costs and their relatively narrow field of application, restricted by the physical properties of the product available.

Postwar developments of the petrochemicals industry, based initially on ethylene oxide and, later on on propylene oxide, led to the investigation of polyalkylene glycols as the basis building blocks for polyurethane foams. Polyester and polyether materials were examined and, whilst in the early years polyester predominated, it was not long before the preferred economics and physical properties of polyethers enabled them, not only to find a major place in this industry, but also to overhaul and very largely replace polyesters.

The above was the history in brief of these famous additions to human comfort and now we will take the foams used in upholstery individually by groups. We will look into their uses, potential and suitability of use by those concerned. We will discuss their properties, their strengths and their weaknesses, their detailed characteristics and the cause of each change in these characteristics; in other words we will try to see how we can choose a good product among the many offered for sale in our country, and how we can make good use of it, which will eventually be for the good of one and all.

GENERAL INFORMATION ON FOAMS

1. Natural rubber foams

These are mainly used nowadays where high resilience is required in a very restricted space, i.e. in aircraft pilot seats, bar stools and similar narrow based pieces of furniture. Also being used in up-market high-value

items but is gradually being replaced by the new cold-cure polyurethanes which do the job at far lower costs. Also being used in countries like Malaysia where rubber is a local product and,to encourage its use, the raw material for artificial foams carry high entry duties and their manufacture is restricted.

2. Polyester foams

These have a restricted use as buoyancy material in life jackets used at sea and in thin form for high-frequency welding to other base material such as artificial leather for padding in furniture and road vehicles.

3. Polyurethane foams

Also called polyether foams: These foams which form the bulk of the foams used in furniture upholstering are manufactured from six components namely (a) Polyol resin, (b) Blowing and gelling catalysts, (c) water, (d) Isocyanate, (e) Silicone oil and (f) Fluorocarbons. Minute variations of some of the components provoke a change in one or many of the parameters set out for foams manufactured for specific end-uses such as seats, backrests, mattresses, etc.

We will now analyse the different parameters required and see how it affects the end user who, in the case of furniture manufacturers is their client, and through him, it also affects them.

3.1 Density

The density of a foam is important from the point of view of both the producer and user alike, because it affects the price, the comfort, the durability and to a certain extent the aesthetics of the final product, namely the piece of furniture. Theoretically a denser foam used for either a seat or a backrest gives better comfort and durability as long as other properties, substantially the resilience, are controlled. By varying the isocyanate content of a formulation for example, the resilience of a foam can be modified from hard to very soft. This is where the economics take over and manufacturers can be tempted to provide the right density but the wrong resilience. The different densities used for seats, backrests and for bedding are

mainly produced more for economic reasons than material comfort.

3.2 Air permeability

The air permeability (air flow through foam) characteristic in a flexible foam is governed by the percentage of open cells in the finished foam, which should be between 75 to 98 percent. Air flow is controlled by (a) the amount of TDI[1/] in the formulation, and (b) the proportion of gelling catalyst, as well as (c) admixture of air in the mix during manufacture. A simple test for air flow is to blow through a piece of foam after taking a deep breath; if you can blow through easily it means that the mater'al contains a high percentage of open cells. The reason I am stressing this point for is that a foam with a high proportion of closed cells feels hard to the touch and may be thought to have a higher density. If such a foam is used, very soon all the closed cells will open up and the cushioning will be flabby and may even disintegrate.

3.3 Tensile strength and elongation at break

A properly formulated foam of any density should show good tensile strength - i.e. should not tear easily when pulled between the fingers. This will affect its ability to hold nails, staples or any other fastening used to hold it in place before the cover is laid on or if the foam needs to be stretched on its frame as in the case of dining room chairs. On thick sheets, the tensile strength can be fairly assessed by pressing one's mid-finger vertically into the foam. If the tensile strength is low one's finger will simply sink in as the foam tears away and practically no resistance is felt. Such foams when used in highly stressed areas as seen in furniture upholstering will give very poor results, and may not be long lasting in use.

3.4 Compression hardness: compression set

For any given density of foam the compression hardness, i.e. the resilience can vary over a wide range. This has partly been dis-

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1/ TDI: Toluene di-Isocyanate

cussed under 3.1 above, even though we must admit that compression hardness, taken as such, does not reflect the quality of a foam; but taken together with other parameters such as density, will start by giving a good appreciation of quality - we can have a good idea how a foam will behave in practice. In our own country we have found that most users prefer a higher compression hardness in their seat material, but on the other hand we do manufacture, upon request, a foam of equal density, namely 25 kg/m^3, but with two thirds of the resilience. This quality is used only by four or five discerning manufacturers.

This implies that taste varies within a market and one should consult with one's clients, and listen to their appreciations, so one can make a good choice of seat or back of bedding material. "Comfort" is a very relative and whimsical thing.

From the above you will note that there are certain parameters which should not vary within too wide a limit as they affect the physical properties of foams as far as strength, durability and ease of use are concerned; whereas there are others which can be made to vary over wide limits as they control mainly user comfort. Generally speaking in the industrialized economies, the tendency is to use softer base material both in the furniture and bedding industries. In the lesser developed countries, the trend is towards materials of higher resistance.

4. Cold cure foams

These are used mainly in moulded form. These foams have been found to possess hysteresis resembling those of, and in many instances even better than those found in natural rubber foams. Their use is becoming more widespread as there is less waste, the product coming out of the mould in finished form. Their present drawback is the high cost of raw materials and their shelf-life which is limited to about six months. And also the costs of moulds, which are not justified in the restricted markets of the less developed countries.

5. Rigid foams

In the furniture trade, at present, the use of rigid and semi-rigid foams is restricted to the manufacture of chair shells and some cabinet components.

In some very particular cases, it is used as a packing material. These end uses have not progressed much during the last five or six years and unless some spectacular developments occur in the research laboratories, the use of rigid foams in our trade will be rather restricted. The large use of rigid foams in building components indirectly assists the furniture trade, and this symbiosis may help develop new uses of rigid foams in the furniture trade itself.

6. Self skinning foams

The polyurethane self-skinning foam process is one which is designed to produce both a cellular core and a non-porous outer skin in one moulding step. The skin is an integral part of the moulding, and articles of furniture made from this process present the advantage of having less steps in production from the raw material to the finished product. The snag is, of course, costs, as a different mould is required for each article to be produced, as in the case of rigid foams. Self-skinning foams are produced in both rigid and flexible form. The machinery required to produce these foams is also different, and the chemicals for the RIM (reaction injection moulding) process as this technique is known are also different from those used in current practice.

Fire hazards

The fire hazard in polyurethane foams is no more pronounced than in other upholstery materials, but unfortunately the combustion gases are poisonous, and this has given polyurethanes a bad name. As the chemical composition of the raw materials cannot be altered, steps have been taken to prevent the rapid spread of flames in the event of a fire, by mixing additives to the foam raw materials at the time of production. The fire retardants added to the foam mixture increase the temperature at which ignition takes place and decrease the speed at which the flames spread. But the fault may not lie wholly with the foams used. For example, the resistance of flexible PUR[1/] foams to lit cigarettes is very much dependent on the upholstery combination. Covering fabrics based on part or whole on cellulose may, under certain circumstances, constitute an ignition risk when exposed to lit cigarettes. With vulnerable

1/ PUR: Polyurethanes

upholstery combinations of this kind, even the inclusion of interliners which are capable of smouldering (such as cotton non-wovens) do not obviate the risk of ignition. Neither, as a rule, does the treating of the cotton with flame retardants have any significant effect on the risk. Simple protection of the upholstery material by means of non-combustible interliners, such as fibreglass fabric, is equally ineffective with regard to the elimination of the danger of smouldering fire.

Resistance to lit cigarettes and the like is greatly increased by the use of covering fabrics and interliners whose melting and heat dissipation properties effectively withdraw sufficient heat from the point of application of the glowing object. Afterglow processes of the sort familiar with cork, which, experience shows, can lead to smouldering fires and the spread of fire under cover, do not occur with insulating materials based on polyurethanes.

With regard to furniture, the combination of the materials used for the upholstery and the design have a decisive influence on the contribution to flame spread. On exposure to radiant heat (eg. components which are already burning), covering fabrics which exhibit thermoplastic behaviour tend to melt and peel giving rise to increased decomposition of the upholstery material and flashover or increased combustion.

The contribution to flame spread can be considerably reduced by selecting suitable covering fabrics with carbonizing properties, and by incorporating special protective interliners.

In addition to the ignition risk and the contribution to flame spread, the hazardous nature of combustible materials is also characterized by their contribution to the overall calorific balance of the fire. If one compares the lower calorific values for polyurethane foams with those of comparable natural products such as rubber, wood, cotton, etc., one finds that polyurethane foams can in no way be considered inferior.

Thus, given equal volumes, polyurethane foams made a similar or considerably smaller contribution to the calorific balance of a fire than do comparable products. As these foams have practically superseded all other types of upholstery material, a fire in a public, overcrowded place such as a discotheque is bound to attract more adverse publicity. All in all polyurethane foams are in no way better nor any worse than upholstery material of other sorts.

Desirable properties of foams for upholstery

We have described in 3.1 to 3.4 above some empirical methods that the user can adopt when he purchases foams for his upholstery shop. We will now discuss this in more scientific terms. Through the diagrams, drawings and data at the end of this section, you can see that the measurement of the characteristics of foams require a considerable amount of apparatus and technique, but this is not the user's business to provide. In normal practice, this is done by (a) the local bureau of standards, (b) the foam manufacturer himself, and (c) the supplier of the raw materials - provided that the foamer sticks to the original formulations used by the raw material manufacturer.

What constitutes a good foam? This is the question that many a furniture manufacturer puts to himself when it comes for him to purchase his padding material. There are no hard and fast and absolute rules to go by, but with time, some code of practice has been established, and more than anything "experience" is more the guideline, and reliability of the foam manufacturer, and the trust that the user puts in him, plays a big role in the choice of the user. The code of practice varies from country to country, and many a time within the same country.

But a consensus has been established, and presently the following is more or less current practice:

Standard polyurethane foams for seating, 23-30 kgs/m^3 density, for backs, 18-23 kgs/m^3 density and for mattresses, 20-25 kgs/m^3 density.

As we have seen in 3.1 above, density does not mean much if not coupled with other parameters, so the table hereunder has been compiled to give a better understanding of the product offered.

Foam density in kgs/m^3	23- 30	28- 23	20- 25
Air permeability ++	115-125	115-125	115-125
Tensile strength (kPa)	100-110	75- 90	80-100
Elongation at break (%)	175-200	160-180	140-160
Compression hardness (kPa)	4- 5	1.5-3.8	3.5-4.5

++ 100 = completely open cells to 350 = completely closed cells.

Foams having characteristics varying between the values mentioned above have been found to give good performance for the respective uses mentioned.

The properties of cold cure and self-skinning foams vary considerably from those of standard foams, and these foams are tailored to their intended specific end-use, so standards for these goods are not established, but are normally set out by the user, and the required raw material supplied by the manufacturers to produce the characteristics set out at time of the purchase.

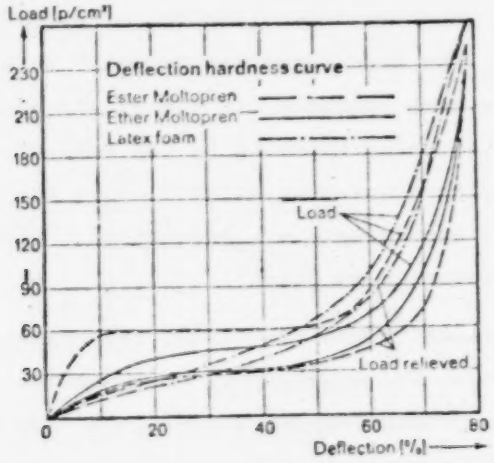

Fig. 1: Deflection hardness curve

Before looking in detail at foam characteristics, we will cast a glance at Fig. 1. We see from there that the deflection hardness curve for Latex foam forms a very smooth curve from low loading to high loading, whereas the curves for the other foams which are of synthetic origin show bumps in their curves, which indicates that their ability to take loads are not even throughout their performance under load. This is what has made the biggest difference between latex foams and their synthetic substitutes. We must note however that the curves for cold cure and self-skinning foams nearly equal the curve for latex foams.

Characterization of properties of flexible foams

1. Density and apparent density

Density is a property which is particularly suitable for the characterization of a material, because it is dependent neither on the geometry of the test specimen nor on the test method used. Moreover, many technological properties of expanded polyurethane materials in particular are very much dependent on their apparent density. It is therefore essential to state the apparent density values whenever discussing the other properties of foams. With expanded materials, the term "apparent density" refers to the fact that the entire volume of the test specimen is taken into account, and not just the much smaller volume actually taken up by the mass of the polymer (for example, with a foam having a apparent density of 24 kgs/m^3, the polymer itself accounts for only approximately 2 percent of the total volume of the sample on which the calculation is based).

With semi-flexible and rigid PUR foams, the apparent density is more or less constant throughout the entire article. Special systems, such as integral skin foams, are produced using formulations and processing methods which result in great differences in apparent density between the skin zone and the core. The determination of density is described in ISO R 1183, and that of the apparent density of foams is described in ISO 845. (Full numbers and titles of all ISO, DIN, BS and other standards are referred to in annex I).

2. Mechanical properties

As in the case with all highly polymeric organic materials, the properties of polyurethanes are also dependent on the temperature at the time of measurement, and the duration of the load or rate of deformation during the test.

Thus mechanical tests can be divided up according to the type of load and the conditions under which it is applied: tensile, compressing and flexion tests, as well as those for hardness, are tests of short duration with low rates of deformation. Impact and shock tests are of short duration with a high rate of deformation. Long term tests using a static load (creep tests) and a vibrating load (dynamic fatigue test) complete the spectrum of properties as regards long term performance. The torsion pendulum test, whereby the shear

modulus and mechanical damping are determined as a function of temperature, is used principally to obtain information on changes of state, and thus to gain an insight into the structure of the macromolecules and their arrangement.

3. Tensile tests

PUR materials are subjected to tensile stresses during production, fabrication and in actual service. Tensile tests (see Fig. 2) are therefore standard for most polyurethane types. Using a predominantly uniaxial load, and

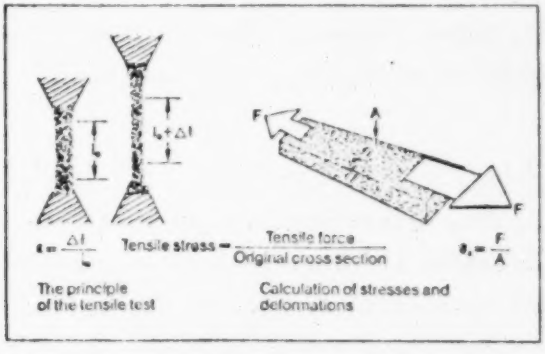

Fig. 2: Tensile test

a constant rate of deformation, the relationship between force and deformation is determined until failure occurs. The force - deformation diagram obtained is converted into a stress-strain diagram (see Fig. 3), in order to be able to

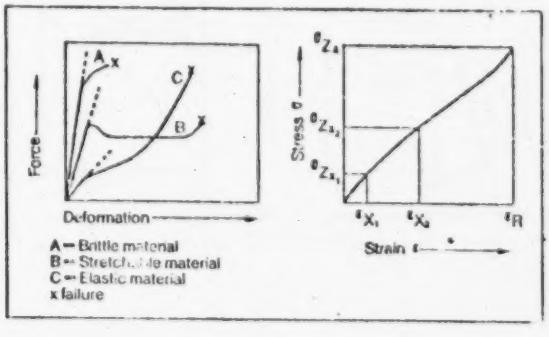

Fig. 3: Force-deformation diagrams

make comparisons between test specimens of different cross sections. In each case, the tensile force is related to the initial cross section of the sepcimen, in order to obtain the tensile stresses. The elongation is obtained from the change in length in relation to the original length.

The rupture stress and associated elongation at break are derived as characteristic values from the stress-strain diagrams. Occasionally, the stress at a particular elongation, eg. 100 percent, is referred to as a characteristic.

4. Tear resistance

In addition to the tensile test, flexible PUR materials are also subjected to a test which determines the resistance to tear propagation of a cut specimen; specially shaped test specimens are used here.

5. Compression test

In compression tests, a test specimen is held between two parallel plates and the force necessary to compress it at a constant deformation rate is determined. From the resultant compressive stress-compression diagrams, the stresses for rigid foams are given as follows: at 10 percent compression for very rigid systems, and at the initial breakdown of the cellular for brittle, hard systems (see Fig. 4).

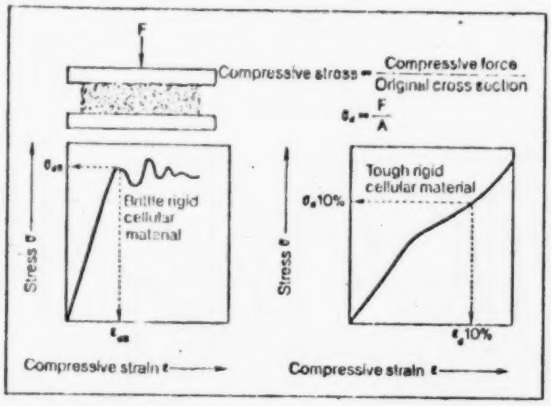

Fig. 4: Stress Compressive Strain Diagrams

The characteristic values and functions obtained from the results of compressive stresses are those most frequently used for classification, particularly in the case of PUR foams. With flexible and semi-flexible systems, they provide reliable information on the behaviour of the foam during load application and removal (in the form of compression hardness curves), and enable a very clear distinction to be made between the various types (see Fig. 5).

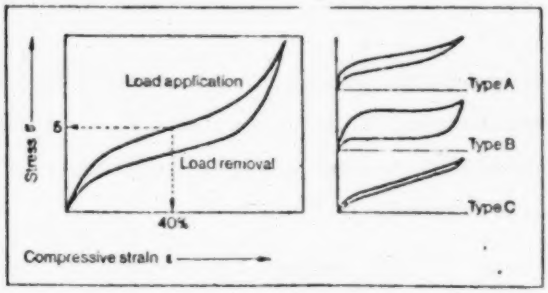

Fig. 5: Compression Hardness Curves

Differences in hardness are evident in the different gradients of the load application and removal curves. Differences in flexibility are indicated by the areas enclosed by the load application and removal curve. Particularly flexible foams give diagrams of type C as shown in Fig. 5. The compressive stresses at 40 percent deformation (compression hardness) are often taken as characteristic values.

6. Indentation hardness tests/hardness determination

In the case of flexible PUR foams in particular, the results of compressive tests are often confused with the data obtained from indentation hardness tests. The indentation hardness test is quite different from the compression test, because the test specimen is compressed by a plunger only over a portion of its surface (see Fig. 6).

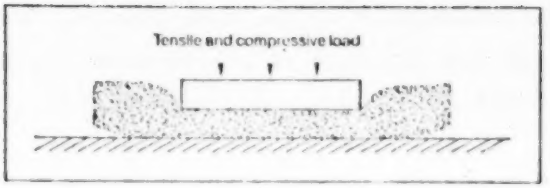

Fig. 6: Principle of the indentation hardness test

The forces necessary to produce indentations to certain distances are represented by force-deformation diagrams, and from these the indentation forces leading to a particular degree of deformation (25%, 40%, 65%) are taken as characteristic values.

Since this method is particularly suitable for the non-destructive testing of mouldings, results obtained on differently shaped test specimens and mouldings are sometimes mistakenly compared. In order to characterize the hardness (shore hardness) of elastomers, a special indentation hardness test is used in which a small, cone-shaped, spring loaded, pin is pressed into the test specimen. The indentation depth is an indication of the hardness of the elastomeric material. These shore hardness data, which are obtained with small, easy to handle instruments, are typical single reference values, and should only be referred to in connection with other technological parameters.

7. Bending tests

Bending loads are often encountered in actual service conditions, and are therefore important, particularly in rigid PUR foams and rigid integral skin PUR foam systems. The bending test laid down for these products in ISO 1209, in which the force necessary to deflect a test specimen under three-point loading is determined (see Fig. 7), is used exclusively for the purpose of comparative tests and quality control.

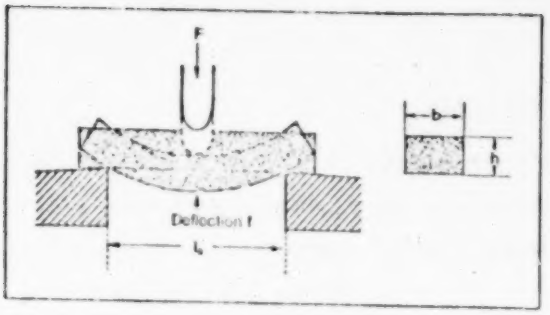

Fig. 7: Bending Test

The data obtained cannot be used for design engineering purposes, because the three-point loading which is a feature of this test prevents pure bending loads from being brought to bear on the test specimen.

8. Shearing tests

The material to be tested is glued between two parallell metal plates which then move in opposite directions (see Fig. 8). The force required to produce failure of the test specimen is converted into shear stresses to give shear strength; the stress-strain curves initially displays an almost linear profile i.e. stress and deformation are proportional to each other. The quotient of a stress and the elongation caused within this linear range is known as the modulus of elasticity.

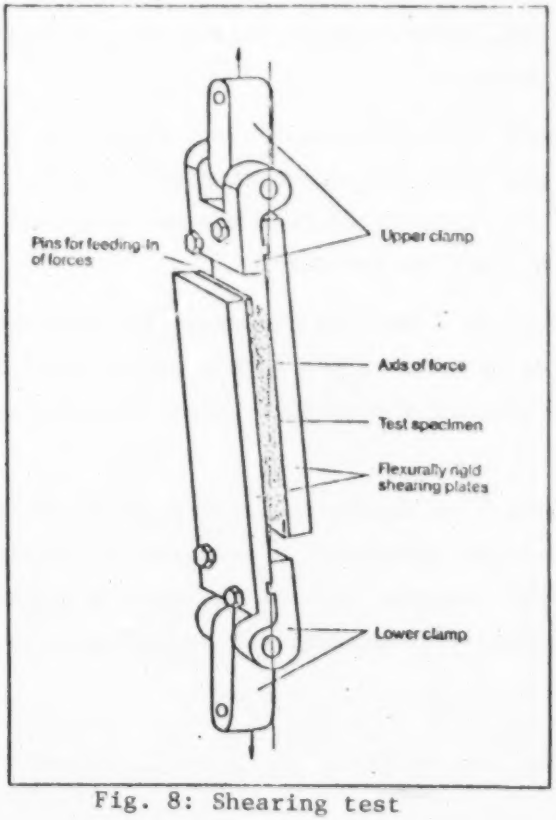

Fig. 8: Shearing test

9. Modulus of elasticity

Each of the stress-strain curves obtained in the above mentioned tests initially displays an almost linear profile, i.e. stress and deformation are proportional to each other. Within this range, all deformation produced by loads of short duration is reversible, i.e. the test specimen reverts to its original shape after removal of the load. The quotient of a stress and the accompanying elongation within this linear range is known as the modulus of elasticity. It is a characteristic parameter of materials, which is used in design engineering whenever the deformation is relatively small and the duration of the forces applied is short. Shear modulus and elasticity modulus are connected by a mathematical equation which contains the transverse contraction ratio.

10. Impact and shock tests

It is often interesting, particularly with regard to PUR foam materials having a relatively high modulus of elasticity, to know about behaviour under load at high rates of deformation. The most important characteristic value in all impact tests is the impact energy which is necessary to deform a test specimen under flexion or tension load until failure occurs. These data make it possible to list the products under test in order to toughness; no conclusions can be drawn from this, however, with regard to the behaviour of mouldings under impact load during service.

In the puncture test, which is chiefly used for thin sheet and film, the energy absorbed by the test specimen during puncture is determined, and the maximum impact force is calculated from the maximum deceleration of the drop hammer which deforms the test specimen.

In cases where PUR foams and expanded PUR elastomers are used for reducing shocks (in the packaging sector, for impact buffers and for bumpers and all-foam seats in automobiles), their shock absorbing and damping properties are of interest.

The determination of impact resilience in accordance with ISO/DIS 2650, in which the ratio of the rebound of a pendulum to its drop height provides a measure for the energy absorbed for the polymer, is a relatively simple process. There are, however, considerable reservations with regard to the use of

this method with foams, since the data obtained with one product are even more dependent on the geometry of the test specimens and the method used than is the case with elastomers. This method should only be used as a check on the uniformity of production.

When designing shock absorbers, relatively complex test methods are essential in order to determine the cushioning factors and the specific energy absorption from the maximum impact of deceleration of various drop weights falling from different heights onto the test specimens. In many cases however, it is impossible to compile the results in the form of characteristic data. So the design engineer has to resort to diagrams showing the dependence of the maximum deceleration on the given parameters for test specimens of various thicknesses.

In order to demonstrate the outstanding adaptability of flexible PUR foams with regard to the requirements of all-foam seats in automobiles, tests on the finished articles are absolutely essential.

11. Tests of long duration

11.1 Creep tests

Because of the dependence of the properties of high polymers on time, PUR materials must also be subjected to creep tests. The deformation of test specimens under constant load and at constant atmospheric conditions (in particular constant temperature) are taken as a function of time, with either tensile, compressive or flexural loads. In this way time-strain curves for various stresses are produced over a period of years, and from these it is possible to read off the time at which a given stress produces a certain strain. From these time-strain curves (see Fig. 9) it is possible, with the aid of the given stresses, to calculate the isochronic stress-strain lines in the range of small deformations for any length of time (eg. 10, 100 or 1000 hours); time dependent moduli (creep moduli) can be taken from the initial linear profile of these stress-strain curves. These moduli of creep are lower than the moduli of elasticity determined in the short duration test. They enable the design engineer to calculate the dimensions of an article in such a way that no inadmissibly great deformation will occur on exposure to loads of long duration.

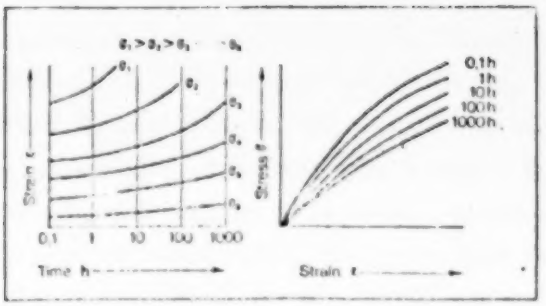

Fig. 9: Illustration of Time-Strain Curves
and Isochronic Stress-Strain Lines

11.2 Compression set

With flexible PUR foams and PUR elastomers, the permanent deformation after constant deformation (see Fig. 10) at a constant temperature is determined as a compression set. This test is a highly abbreviated creep test under constant deformation, in which the time and temperature parameters are also set at fixed values (single point measurement). The conclusiveness of this test for practical applications is frequently overvalued.

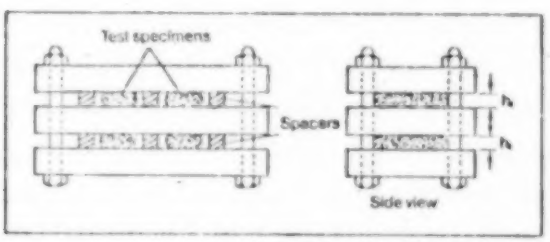

Fig. 10: Principle of Determination of Compression Set.

11.3 Long-term tests with alternating stress

PUR materials in service are exposed not only to constant loads, but also to alternating loads over long periods of time. This type of load on eg. cushioning materials is reproduced in the dynamic fatigue test in accordance with DIN 53574 (see Fig. 11).

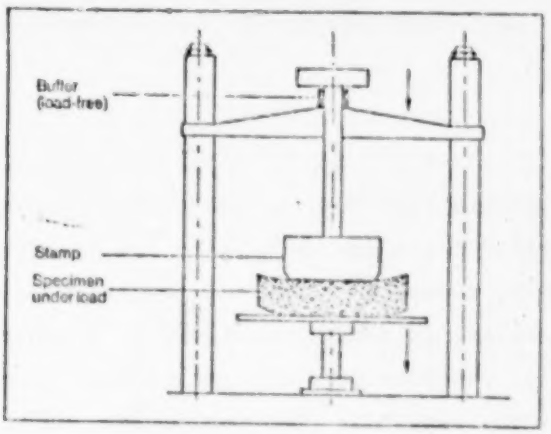

Fig. 11: Principle of Dynamic Fatigue Test

In this test a mass of 75 kgs is periodically applied to and removed from the test specimens usually used for the determination of indentation hardness. The test is interrupted after 80.000 load reversals and the change in hardness is determined using the indentation hardness test method. Results obtained in this way show good correlation with changes in hardness which occur during actual service. Dynamic fatigue tests are carried out on PUR elastomers and semi-flexible PUR integral skin foams, mostly under flexural (bending) laod. In an intensified form of this test, the section of the specimen in which the greatest deformation occurs is punctured using a small needle. After a prescribed number of load cycles, the cut growth - i.e. enlargement (normally a tear in one or more directions from the centre) of the original hole made by the needle - of this hole is measured.

11.4 Abrasion and wear tests

Abrasion tests are intended to assess the wear to be expected on PUR elastomers and shoe sole materials based on semi-flexible PUR integral skin foam systems, by determining the loss in volume of a test specimen on rubbing with an abrasive of a specified degree of hardness. These tests are suitable for quality control testing, to ensure that specifications are being maintained; the results have only a limited value, however, as regards the prediction of abrasion behaviour in actual service.

11.5 Ageing tests

All irreversible chemical and physical changes which take place in a material in the course of time are ageing processes. The changes effected by repeated mechanical loading have already been dealt with. There is, in addition, a number of other causes of ageing. Thus, for example, exposure to light (particularly the UV portion of the spectrum) may result in photo-oxidation, or splitting of the chemical bonds. This usually leads to a reduction in strength values. Discolouration cracking and blooming may also be observed. Exposure tests are intended to reproduce this type of phenomena as encountered in service. In the Xenon- and Weather-mometer tests, the effect of rain, as well as that of exposure of light can be simulated. By intensifying these influencing parameters, an attempt is made to accelerate ageing. One must however be careful not to over-estimate the value of artificial exposure tests of this type. There have been numercus cases in which the order of merit of products according to artificial ageing has been very different from that obtained in actual outdoor use.

Of particular importance wiht regard to testing of PUR materials is the determination of resistance to water and water vapour at elevated temperatures. To this end tests are carried out, chiefly steam rooms, in which the materials are stored in climatic test cabinets, preserving jars and (at temperature in excess of 100°C) in steam autoclaves. It should be pointed out here that attempts to accelerate the test by increasing the temperature can give rise to decomposition processes

in the PUR material of a sort which would not occur in practice (in many cases increasing the temperature causes more than just a thermodynamically calculatable increase in the speed of the reaction.)

Since PUR materials have such a broad property spectrum these remarks can only touch on a few important test methods.

11.6 Determination of the dependence of materials characteristics on temperature

Tensile, compression and flexural tests can be carried out in temperature controlled cabinets in order to obtain stress-strain curves over a wide range of temperature. In addition to the strength properties, which are greatly influenced by temperature, and the type of failure, the elasticity moduli determined fromthe curve at different temperatures are of particular interest; in the form of elasticity modulus-temperature curves they make an important contribution to the characterization of polymeric materials.

11.7 The torsion pendulum test

Modulus-temperature curves are easier to determine by the torsion pendulum test. The test specimen taken from the material under investigation is used as a torsion spring; it bears a mass in the form of a disk and can be stimulated to produce free vibrations. The shear modulus is calculated from the dimensions and the frequency of vibration. From the reduction in vibration amplitude one obtains the damping factor "d" (also characterized as tan δ), which is a measure of the work done by deformation, which is converted into heat within the test specimen. When carried out at set temperature intervals, the test gives the profiles for modulus and mechanical damping as a function of the temperature, from which relationship between the microstructure of the material and the macroscopic properties can be illustrated.

In the glassy state, i.e. when the test specimen attains the temperature at which damping is found, polymers have a high modulus (see fig. 12), while damping is low.

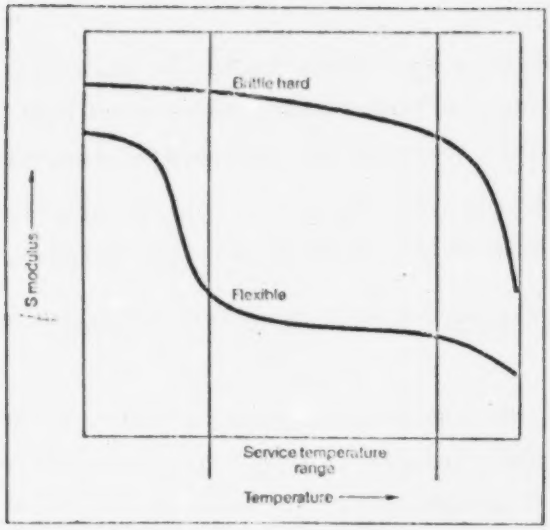

Fig. 12: Shear Modulus Curves

The linear deformation range is small, and sizeable deformation lead to stretching at ordinary temperatures and failure. On account of the high modulus, polymeric materials are often deliberately developed in such a way that they are in a glassy state within the service temperature range.

In the transitional range, the modulus falls by several powers of ten, during which the damping factor passes through a maximum. The onset of softening is usually marked by an intersection, and the associated temperature is termed the second order-transition temperature. The temperature at which maximum damping is found is usually known as the glass transition temperature. As the temperature continues to increase, a plateau occurs in the modulus profile of many polymers. Within this temperature range the material behaves practically like rubber. It is softer than in the glassy state, and can withstand great reversible (elastic) deformation. PUR elastomers and flexible PUR foams exhibit this behaviour over the entire service temperature range. Many manerials only exhibit rubber elastic-behaviour over a narrow range of temperature. When the glass transition temperature is exceeded, they are transformed into melts, in other words they become thermoplastic. In between these two extremes, there are numerous transitional stages, such as that of thermoformable PUR elastomers.

12. Determination of cell structure

The apparatus described in Fig. 13 below permits a determination of the percentages of open and closed cells in foams. The measuring principle is based on the Boyle-Mariotte law. The cell volume is determined from the change in pressure resulting from a predetermined change in volume.

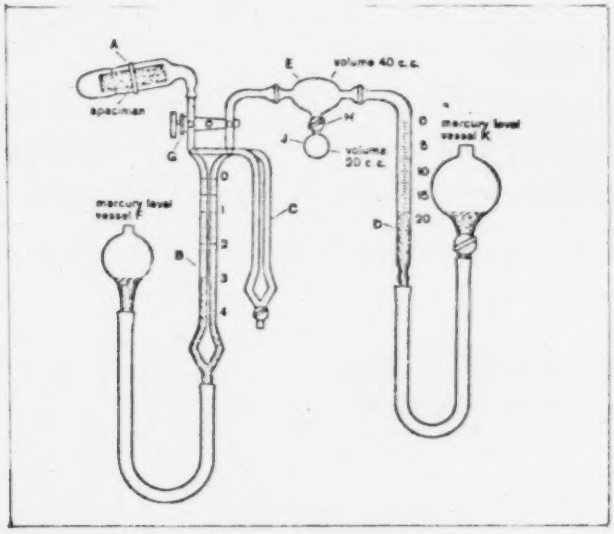

Fig. 13: Equipment to determine cell structure

The apparatus shown in the figure above consists essentially of the specimen chamber A which is connected with the reference chamber E by two paralell pressure gauges B and C. Pressure gauge B is provided with a mercury level vessel F, while pressure gauge C, as a precision instrument, is filled with dibutyl phtalate or another liquid of low density and low vapour pressure. The reference chamber E is connected with a burette D and a mercury level vessel K. The apparatus is divided into two systems by the pressure gauge liquids.

The sample container system includes the sample chamber A, the left half of the mercury pressure gauge B and the left half of the auxilliary pressure gauge C. The reference container system consists of the flask E, the auxilliary flask J, the right halves of the mercury pressure guage B and the auxilliary pressure gauge C and the burette D.

The air volume displaced by the foam specimen consists of the space taken up by the closed cells and the cell walls. The test procedure consists essentially of a comparison of the volumes of both systems with and without specimens. The air volume displaced by the foam specimen in the left half is reproduced by removing a corresponding volume in the right part of the apparatus (compensation principle). Agreement between the left and the right volume is determined by pressure comparison of the air located in the two volumes following an equal change in volume.

13. Fastening properties

We have analysed the characteristics required in a good foam, now we will see that the properties we want are not only for good resilience and durability, but are also required for another purpose, namely fastening.

Foams can be tacked on, stapled, welded, stitched and also glued.

Tacks

Except on the smallest of jobs tacks are rarely used nowadays as they are too time consuming and tedious to lay and fix.

Staples

Instead, staples are used, as they are easier to fix, kinder to the foam through their larger bearing surface, and also all in all they are cheaper in the short run, whether laid by hand pressure or by air or electric action. They also reach in the confined spaces, where hand and tack cannot be used. They do not cause split lines in the frames or bases as closely spaced tacks would do. Add, when time comes for repair they are easily removed and replaced. As wide a crown as possible should be used to minimize tear in the foam.

Welding

Foams are successfully welded by high frequency welders, but this is only feasible if fairly large quantities of one item are required, as the electrodes should be set according to the exact pattern to be welded, so a different set of electrodes and subsequent adjustment to the machine are required each time the pattern is changed.

Stitching

Foams, at least in thin sheet form can be easily stitched. The method used is (a) a low pressure on the claw foot, (b) wide stitches and (c) a strip of paper is inserted between the machine bed and the foam, and another between the foot and the foam. Where foams are to be used in highly stressed areas, stitching is not recommended.

Glueing

By far the most widely used fastening method used for fixing plastic foams is by glueing. With modern glues, the method is foolproof if properly carried out. The best adhesives are neoprene based contact adhesives, and they give an even and smooth continuous line of fixing. These glues can be spread by a spatula, by a dispenser or by a spray gun if a sprayable grade is prescribed at the time of the pruchase. The adhesive should be spread evenly in a thin coat on both surfaces to be glued and allowed to stand a few minutes to reach "tacky" point, when both surfaces are brought together and pressed firmly together. By this method foams can be glued to wood, metal, particle board, plywood, and even to glass. These contact adhesives are very inflammable in nature and care should be taken in their use. Well ventilated premises and firm closure of containers after use will greatly minimize the risk of fire and the inhalation of solvents which may be injurious to the health of the operators.

Some grades of PVA glues have been recommended for the glueing of foams, but on trial these have been found to have a very long drying time and to leave a hard glue-line which tends to show under the upholstery material.

ANNEX I

STANDARDS FOR FOAMS USED IN UPHOLSTERY

ASTN-D 1692	Flammability of plastic sheeting and cellular plastics.
ISO R 3795	Road Vehicles - Determination of burning behaviour of interior materials for motor vehicles.
DIN 53572	Compression set in polyurethane foams. Tests at various percentages of compression.
DIN 53577	Compression hardness in polyurethane foams at 40% compression.
DIN 53574	Polyurethane cellular materials: Fatigue tests with constant load amplitude.
ASTM 1564-755	Indentation hardness tests on cellular materials.
DIN 53420	Density determination tests on flexible polyurethane foams.
DIN 53571	Tests for tensile strength in polyurethane cellular materials.
DIN 53575	Tear resistance tests in flexible urethane foams.